

Mastery is measured by the number of mistakes made on the way

~~The second reason deep practice is a strange concept is that it takes events that we normally strive to avoid—namely, mistakes—and turns them into skills. To understand how deep practice works, then, it's first useful to consider the unexpected but crucial importance of errors to the learning process. In fact, let's consider an extreme example, which arrives in the form of a question: how do you get good at something when making a mistake has a decent chance of killing you?~~

EDWIN LINK'S UNUSUAL DEVICE

In the winter of 1934 President Franklin Roosevelt had a problem. Pilots in the U.S. Army Air Corps—by all accounts the military's most skilled, combat-ready airmen—were dying in crashes. On February 23 a pilot drowned when he landed off the New Jersey coast; another was killed when his plane cartwheeled into a Texas ditch. On March 9 four more pilots died when their planes crashed in Florida, Ohio, and Wyoming. The carnage was not caused by a war. The pilots were simply trying to fly through winter storms, delivering the U.S. mail.

The crashes could be traced to a corporate scandal. A recent Senate investigation had exposed a multimillion-dollar price-fixing scheme among the commercial airlines contracted to carry the U.S. mail. President Roosevelt had swiftly responded by canceling the contracts. To take over mail delivery, the president called upon the Air Corps, whose generals were eager to demonstrate their pilots' willingness and bravery. (They also wanted to show Roosevelt that the Air Corps deserved the status of a full military branch, equal to the Army and Navy.) Those generals were mostly right about Air

Corps pilots: they were willing, and they were brave. But in the harsh winter storms of 1934, Air Corps pilots kept crashing. Early on the morning of March 10, after the ninth pilot died in twenty days, FDR summoned General Benjamin Foulois, commander of the Air Corps, to the White House. "General," the president said fiercely, "when are these airmail killings going to stop?"

It was a good question, one that Roosevelt might have directed at the whole enterprise of pilot training. Early pilot training was built on the bedrock belief that good pilots are born, not made. Most programs followed an identical procedure: the instructor would take the prospective student up in the plane and execute a series of loops and rolls. If the student did not get sick, he was deemed to have the capability to become a pilot and, after several weeks of ground school, was gradually allowed to handle the controls. Trainees learned by taxiing, or "penguin-hopping" in stubby-winged crafts, or they flew and hoped. (Lucky Lindy's nickname was well earned.) The system didn't work too well. Early fatality rates at some Army aviation schools approached 25 percent; in 1912 eight of the fourteen U.S. Army pilots died in crashes. By 1934 techniques and technology had been refined but training remained primitive. The Airmail Fiasco, as Roosevelt's problem swiftly became known, raised the question pointedly: was there a better way to learn to fly?

The answer came from an unlikely source: Edwin Albert Link, Jr., the son of a piano and organ maker from Binghamton, New York, who grew up working at his father's factory. Skinny, beak-nosed, and epically stubborn, Link was a tinkerer by nature. When he was sixteen, he fell in love with flying and took a \$50 lesson from Sydney Chaplin (half brother of the movie star). "For the better part of that hour we did

loops and spins and buzzed everything in sight," Link later recalled. "Thank heaven I didn't get sick, but when we got down, I hadn't touched the controls at all. I thought, 'That's a hell of a way to teach someone to fly.'"

Link's fascination grew. He started hanging around local barnstormers, cadging lessons. Link's father didn't appreciate his interest in flying—he briefly fired young Edwin from his job at the organ factory when he found out about it. But Link kept at it, eventually purchasing a four-seat Cessna. All the while his tinkerer's mind kept circling the notion of improving pilot training. In 1927, seven years after his initial lesson with Chaplin, Link went to work. Borrowing bellows and pneumatic pumps from the organ factory, he built a device that compressed the key elements of a plane into a space slightly roomier than a bathtub. It featured stubby prehensile wings, a tiny tail, an instrument panel, and an electric motor that made the device roll, pitch, and yaw in response to the pilot controls. A small light on the nose lit up when the pilot made an error. Link christened it the Link Aviation Trainer and put up an advertisement: he would teach regular flying and instrument flying—that is, the ability to fly blind through fog and storms while relying on gauges alone. He would teach pilots to fly in half the time of regular training and at a fraction of the cost.

To say that the world overlooked Link's trainer wouldn't be accurate. The truth was, the world looked at it and issued a resounding and conclusive no. No one he approached seemed interested in Link's device—not the military academies, not private flying schools, not even barnstormers. After all, how could you learn to fly in a child's toy? No less an authority than the U.S. Patent Office declared Link's trainer a "novel, profitable amusement device." And so it seemed destined to

become. While Link sold fifty trainers to amusement parks and penny arcades, only two reached actual training facilities: one he sold to a Navy airfield in Pensacola, Florida, and another he loaned to the New Jersey National Guard unit in Newark. By the early 1930s Link was reduced to hauling one of his trainers on a flatbed truck to county fairgrounds, charging twenty-five cents a ride.

When the Airmail Fiasco hit in the winter of 1934, however, a group of Air Corps brass grew desperate. Casey Jones, a veteran pilot who had trained many of the Army pilots, recalled Link's trainer and persuaded a group of Air Corps officers to take a second look. In early March, Link was summoned to fly from his home in Cortland, New York, to Newark to demonstrate the trainer he'd loaned to the National Guard. The appointed day was cloudy, with zero visibility, nasty winds, and driving rain. The Air Corps commanders, by now familiar with the possible outcomes of such hazards, surmised that no pilot, no matter how brave or skilled, could possibly fly in such weather. They were just leaving the field when they heard a telltale drone overhead in the clouds, steadily descending. Link's plane appeared as a ghost, materializing only a few feet above the runway, kissed down with a perfect landing, and taxied up to the surprised generals. The skinny fellow did not look like Lindbergh, but he flew like him—and on instruments, no less. Link proceeded to demonstrate his trainer, and in one of the first recorded instances of nerd power trumping military tradition, the officers understood its potential. The generals ordered the first shipment of Link trainers. Seven years later, World War II began, and with it the need to transform thousands of unskilled youth into pilots as quickly and safely as possible. That need was answered by ten thousand Link trainers; by the end of the war, a half-million

airmen had logged millions of hours in what they fondly called "The Blue Box."* In 1947 the Air Corps became the U.S. Air Force, and Link went on to build simulators for jets, bombers, and the lunar module for the Apollo mission.

Edwin Link's trainer worked so well for the same reason you scored 300 percent better on Bjork's blank-letter test. Link's trainer permitted pilots to practice more deeply, to stop, struggle, make errors, and learn from them. During a few hours in a Link trainer, a pilot could "take off" and "land" a dozen times on instruments. He could dive, stall, and recover, spending hours inhabiting the sweet spot at the edge of his capabilities in ways he could never risk in an actual plane. The Air Corps pilots who trained in Links were no braver or smarter than the ones who crashed. They simply had the opportunity to practice more deeply.

This idea of deep practice makes perfect sense in training for dangerous jobs like those of fighter pilots and astronauts. It gets interesting, however, when we apply it to other kinds of skills. Like, for instance, those of Brazil's soccer players.

BRAZIL'S SECRET WEAPON

Like many sports fans around the world, soccer coach Simon Clifford was fascinated by the supernatural skills of Brazilian soccer players. Unlike most fans, however, he decided to go to Brazil to see if he could find out how they developed those

* The military's regard for the efficacy of Link's trainers apparently went only so far. Link was permitted to sell hundreds of his devices to Japan, Germany, and the USSR in the years leading up to World War II, creating a situation where both sides in many dog-fights were, training-wise, evenly matched.

skills. This was an unusually ambitious initiative on Clifford's part, considering that he had gained all his coaching experience at a Catholic elementary school in the soccer non-hotbed of Leeds, England. Then again, Clifford is not what you'd call usual. He's tall and dashing, handsome and radiates the sort of charismatic, bulletproof confidence one usually associates with missionaries and emperors. (In his early twenties Clifford was severely injured in a freak soccer accident—suffering internal organ damage, kidney removal—and perhaps as a result he approaches each day with immoderate zeal.) In the summer of 1997, when he was twenty-six, Clifford borrowed \$8,000 from his teachers' union and set out for Brazil toting a backpack, a video camera, and a notebook full of phone numbers he'd cajoled from a Brazilian player he'd met.

Once there, Clifford spent most of his time exploring the thronging expanse of São Paulo, sleeping in roach-infested dormitories by night, scribbling notes by day. He saw many things he'd expected to find: the passion, the tradition, the highly organized training centers, the long practice sessions. (Teenage players at Brazilian soccer academies log twenty hours per week, compared with five hours per week for their British counterparts.) He saw the towering poverty of the favelas, and the desperation in the players' eyes.

But Clifford also saw something he didn't expect: a strange game. It resembled soccer, if soccer were played inside a phone booth and dosed with amphetamines. The ball was half the size but weighed twice as much; it hardly bounced at all. The players trained, not on a vast expanse of grass field, but on basketball-court-size patches of concrete, wooden floor, and dirt. Each side, instead of having eleven players, had five or six. In its rhythm and blinding speed, the game resembled basketball or hockey more than soccer: it consisted of an

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